George C. Marshall Space Flight Center
National Aeronautics and Space Administration

Plasmaspheric H^+, He^+, He^{++}, O^+, and O^{++} Densities and Temperatures

D. L. Gallagher1, P. D. Craven1, R. H. Comfort2

1 NASA/Marshall Space Flight Center
2 University of Alabama in Huntsville

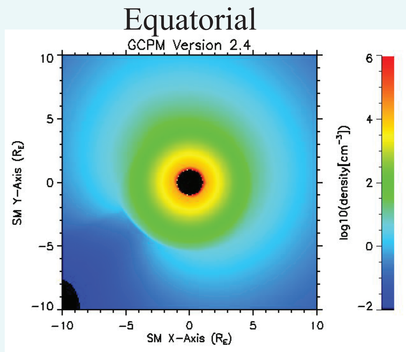
ABSTRACT

Thermal plasmaspheric densities and temperatures for five ion species have recently become available, even though these quantities were derived some time ago from the Retarding Ion Mass Spectrometer onboard the Dynamics Explorer 1 satellite over the years 1981-1984. Some of the quantitative properties are presented. Densities are found to have one behavior with lessor statistical variation below about L=2 and another with much greater variability above that L-shell. Temperatures also have a behavior difference between low and higher L-values. The density ratio He++/H+ is the best behaved with values of about 0.2% that slightly increase with increasing L. Unlike the He+/H+ density ratio that on average decreases with increasing L-value, the O+/H+ and O++/H+ density ratios have decreasing values below about L=2 and increasing average ratios at higher L-values. Hydrogen ion temperatures range from about 0.2 eV to several 10s of eV for a few measurements, although the bulk of the observations are of temperatures below 3 eV, again increasing with L-value. The temperature ratios of He+/H+ are tightly ordered around 1.0 except for the middle plasmasphere between L=3.5 and 4.5 where He+ temperatures can be significantly higher. The temperatures of He++, O+, and O++ are consistently higher than H+.

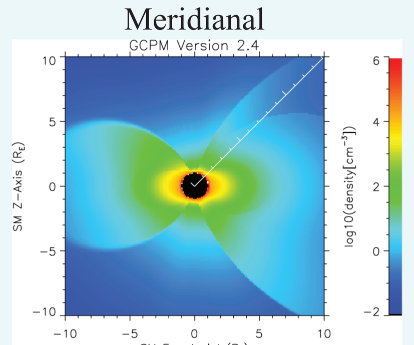
OBJECTIVE

The objective of this effort is to create a new, updated Global Core Plasma Model (GCPM), first published by Gallagher et al., *JGR, 105*, 18819, 2000. GCPM is an empirical, global model of thermal plasma density intended to provide typical concentrations of H+ and He+ in the inner magnetosphere. The model design was initially based on 30 years of published regional models and intended to be smooth in value and gradient. Samples of the existing GCPM are shown below.

Equatorial



Meridional



The objective for a new GCPM, call it GCPM* for convenience, is to take advantage of extensive moment calculations performed with the Retarding Ion Mass Spectrometer (RIMS) data that provide densities and temperatures for five ions: H+, He+, He++, O+, and O++. Further, it is intended that the new model take advantage of what has been learned from global plasmaspheric images obtained by the IMAGE Mission Extreme Ultraviolet (EUV) Instrument [Sandel, et al., *Space Sci. Rev., 91*, 197, 2000]. That knowledge is of a global morphology of the plasmaspheric response to ever changing magnetospheric convection, whose recognition may enable new opportunities to achieve a more ordered assembly of in situ measurements. Polar cap and other more recently published observations are also to be included in the new CGPCM*.

SUMMARY

Three areas are shown to the right. The first provides a quick look at an initial set of equations that can be used to describe some, but not all, of ion densities and temperatures. This is a preliminary look at the products sought through this investigation. Perhaps not unexpectedly there is a perponderance of relatively ordered relationships between ions. Sometimes that connection is best ordered spatially by L-shell and sometimes by altitude or radial distance. The gaps in this solution set result from greater than one order in magnitude scatter in ion density or temperature in these plots. Naturally it is expected that there will be a strong dependence on geophysical or space weather conditions, even when different ions respond similarly as indicated by somewhat better behaved ion ratios.

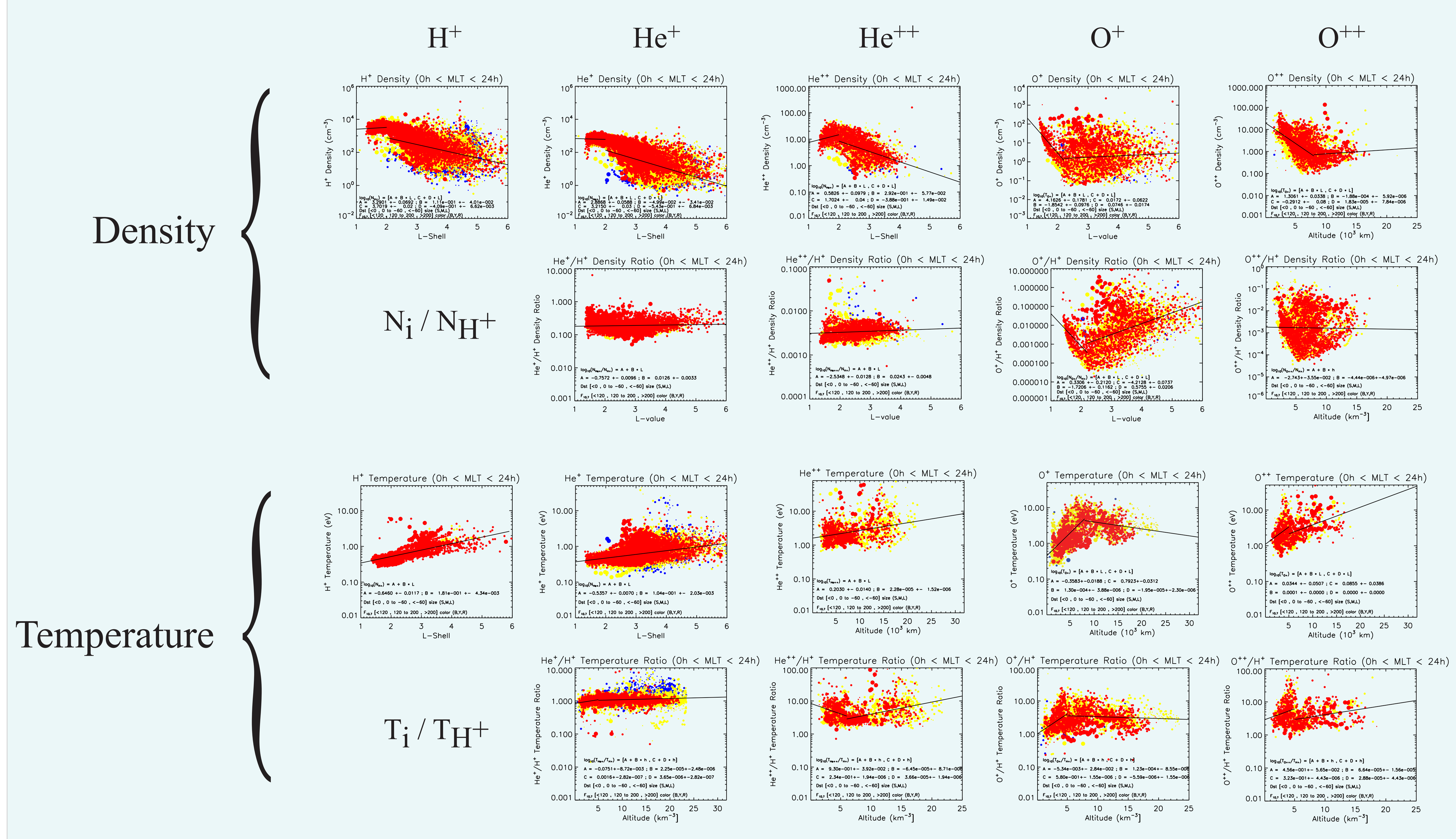
The second area shows a sampling of ion densities and temperatures as a function of L-shell and altitude. The fits shown are simple and do not yet include differentiation by space weather conditions.

The third area shows the beginnings of the analysis of the influence of space weather conditions at low altitude on H+ density. The center graphic shows the spatial coverage in the magnetic equatorial plane Color is used here to provide a qualitative measure of the logarithm of density, where red is the highest and blue the lowest. The surrounding plots use colored dots to represent three ranges of $F_{10.7}$ intensity and three dot sizes to represent ranges of the Dst index. The same color and dot scheme is also used in the DATASET display to the right. The density profile as a function of altitude suggests a MLT dependence. Increased density appears correlated with increasing $F_{10.7}$, as is expected at low altitude. Considerable scatter remains. Scatter is unavoidable in an empirical model of typical densities and temperatures. However, the next step in this investigation is to sort measurements based on a new approach that is intended to capture the morphology of plasmaspheric evolution from quite, to erosion and plume formation, through recovery during varying convection conditions.

SOLUTION SET

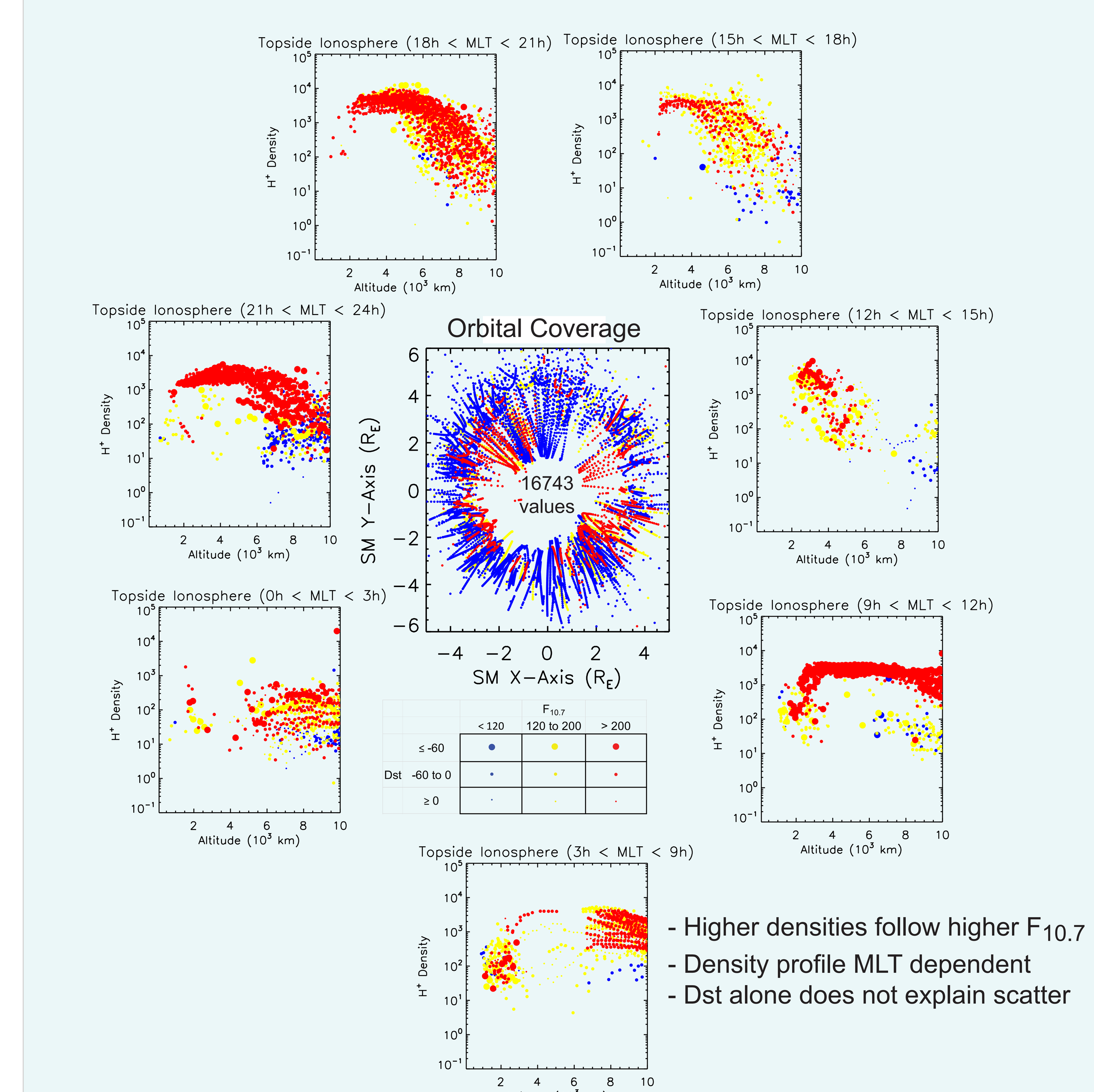
	H^+	He^+	He^{++}	O^+	O^{++}
Density		$\log_{10}(N_{He+}/N_{H+}) = A + B * L$ A = −0.7572 +− 0.0096 ; B = 0.0126 +− 0.0033	$\log_{10}(N_{He++}/N_{H+}) = A + B * L$ A = −2.5348 +− 0.0128 ; B = 0.0243 +− 0.0048		
Temperature	$\log_{10}(N_{H+}) = A + B * L$ A = −0.6460 +− 0.0117 ; B = 1.81e−001 +− 4.34e−003	$\log_{10}(T_{He+}/T_{H+}) = [A + B * h , C + D * h]$ A = −0.0751+−8.72e−003 ; B = 2.25e−005+−2.48e−006 C = 0.0016+−2.82e−007 ; D = 3.65e−006+−2.82e−007	$\log_{10}(T_{He++}/T_{H+}) = [A + B * h , C + D * h]$ A = 9.30e−001+− 3.92e−002 ; B = −6.45e−005+− 8.71e−006 C = 2.34e−001+− 1.94e−006 ; D = 3.66e−005+− 1.94e−006	$\log_{10}(T_{O+}) = [A + B * L , C + D * L]$ A = −0.3583+−0.0188 ; C = 0.7923+−0.0312 B = 1.30e−004+− 3.88e−006 ; D = −1.95e−005+−2.30e−006	$\log_{10}(T_{O++}/T_{H+}) = [A + B * h , C + D * h]$ A = 4.56e−001+− 5.65e−002 ; B = 6.64e−005+− 1.56e−005 C = 3.23e−001+− 4.43e−006 ; D = 2.88e−005+− 4.43e−006

DATASET



H+ LOW ALTITUDE ANALYSIS

A Distinct Break in H+ Densities Distinguishes High Topside Ionosphere from Higher Altitudes



CANDIDATE INDEPENDENT VARIABLES (population histograms)